UNIVERSIDAD
PANAMERICANA

Seismic Engineering

Assigment # 1

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Earthquake Engineering

Assigment #1: Seismology

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1. What are the differences between an interplate and intraplate earthquake. Where does this type of earthquake can be found?

   Interplate earthquakes, which happen where tectonic plates meet, are the most frequent type of earthquake. These earthquakes often occur in areas like the Pacific Ring of Fire and are usually more powerful due to the large sections of Earth's crust involved in the movement.

   Intraplate earthquakes occur inside a single tectonic plate, away from plate boundaries. These earthquakes happen in the middle of plates, like in the central United States. While they are less frequent and typically less powerful than interplate earthquakes, they can still cause substantial damage because of their unexpected nature and the lack of preparation in these areas.

2. Mention and describe the types of plate boundaries. What causes them?

   Divergent Boundaries:

   Where tectonic plates diverge, they are pulling apart. As they separate, hot material from deep within the Earth rises to fill the space, creating new crust as it cools.

   The primary cause of divergent boundaries is the upward flow of molten rock from the Earth's interior, which pushes the plates apart. This process is commonly seen at mid-ocean ridges, where new oceanic crust is formed.

   Convergent boundaries:

   When two big pieces of Earth's land (called tectonic plates) bump into each other, it's called a convergent boundary. Often, one piece goes under the other, which is called

subduction. This happens because the Earth's inside is always moving. When the plate goes deep into the Earth, it gets hot and melts, which can make volcanoes. These places where plates crash together are also where we get a lot of big earthquakes.

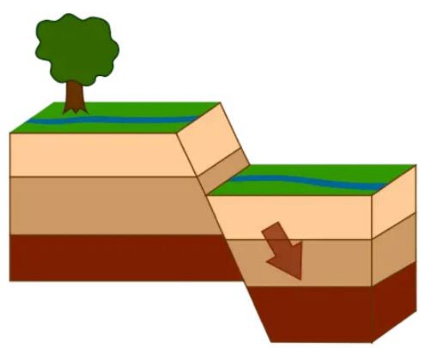
Transform boundaries:

Where two tectonic plates slide past each other sideways. They don't create or destroy any crust. The plates move in different directions or at different speeds, causing friction. When this friction gets too much, it can cause earthquakes.

3. Which are the types of faulting mechanisms and what are their characteristics? (Add a sketch).

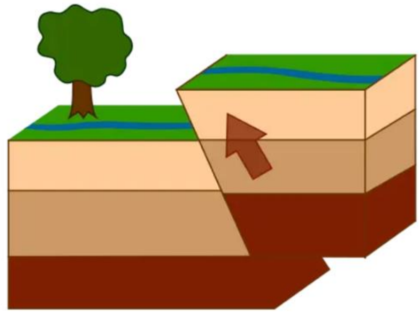
Normal Faults:

It’s like a crack in the ground where one side slides down. That's a normal fault. The upper part of the crack is called the "hanging wall" and the lower part, "footwall". This happens when the Earth is stretched and pulled apart. It's common in places where the big pieces of land (tectonic plates) are moving away from each other.



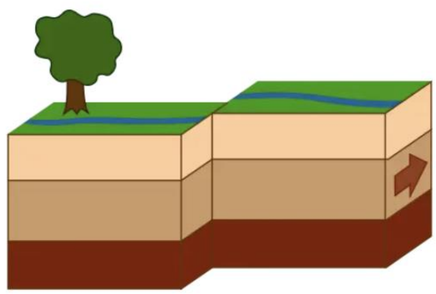
Reverse/ Thrust Fault:

It’s like a crack in the ground where one side slides up compared to the other. That's a reverse fault. The upper part of the crack is called the "hanging wall" and the lower part is called the "footwall". This happens when the Earth's land is being squeezed together. It's common in places where the big pieces of land (called tectonic plates) are crashing into each other. A reverse fault that's very flat is called a "thrust fault".



Strike – slip Fault:

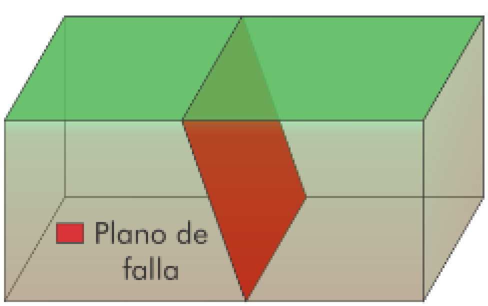
It´s like a crack in the ground where two sides slide past each other sideways, like a sliding door. That's a strike-slip fault. They mostly move sideways, not up and down. This happens in places where the Earth's big pieces of land (called tectonic plates) are sliding past each other. A famous example is the San Andreas Fault in California.

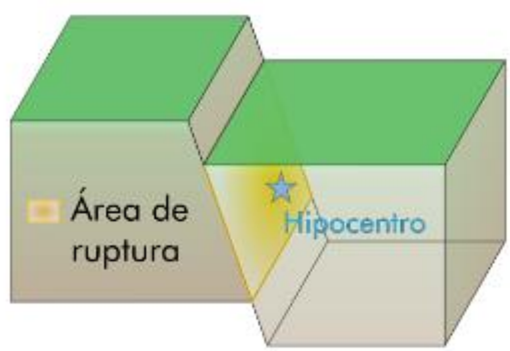


4. Name and describe the 3 parameters used to describe a local seismic fault. (Add a sketch).

   1) Rupture Area:

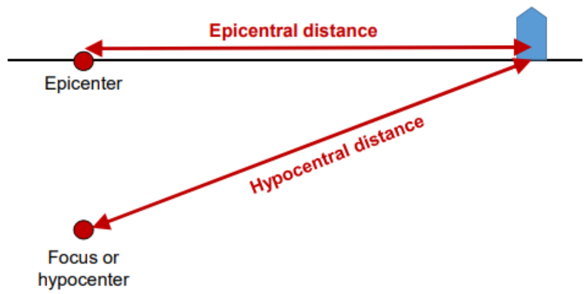
   This is the size of the crack in the earth that causes an earthquake. The bigger the crack, the stronger the earthquake. It's measured in square meters.





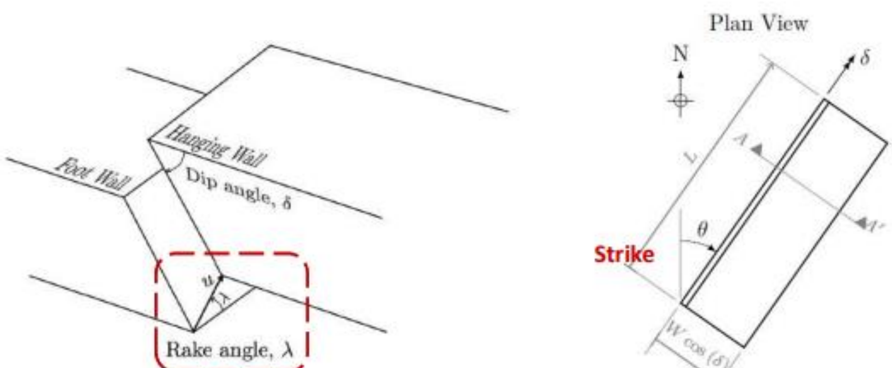
2) Displacement (slip):

This is how far the earth moves when it cracks during an earthquake. The more it moves, the more powerful the earthquake is. It's measured in meters.



3) Seismic moment (M0):

This is a way to measure how powerful an earthquake was. It's like measuring the size of the crack in the earth, how far the earth moved, and how strong the rocks are. The bigger the seismic moment, the stronger the earthquake. It's measured in newton-meters.



5. Based on an important earthquake, provide a report (2 pages long) in which at least the following information is provided:

Mexico City Earthquake, 1985

In my personal opinion, the most important earthquake was the one that happened in Mexico City in 1985. While it may not have been the strongest earthquake ever recorded in the world, it was the most powerful one experienced in Mexico. This event was a turning point for the country, leading to a greater awareness of seismic activity and its impact on buildings, especially high-rise structures. The earthquake

made it clear that understanding earthquakes and earth movements had to become a major concern for future generations.

The Mexico City earthquake occurred on September 19, 1985. It started around 7:00 in the morning and had a magnitude of 8.1 on the Richter scale. This earthquake resulted in the deaths of thousands of Mexicans. The government officially reported 3,700 deaths, but the Mexican Red Cross estimates that more than 10,000 people died. The high number of casualties was partly due to the time the earthquake struck and the fact that many buildings at the time were not prepared to withstand such a powerful quake.

The epicenter of the earthquake was located in the Pacific Ocean, near the mouth of the Balsas River, off the coast of the state of Michoacán. The exact coordinates of the epicenter are 18°11′N 102°32′O / 18.19, -102.53, and the hypocenter was about 15 kilometers deep under the Earth's crust. The earthquake was caused by a reverse fault, which is typical in subduction zones. In a reverse fault, the upper block moves upwards relative to the lower block. This type of movement is usually caused by compression in the Earth's crust.

This earthquake was classified as a major earthquake, which is common in subduction zones. In such earthquakes, the fault rupture generally involves significant vertical displacement, as the upper continental plate is pushed upwards while the oceanic plate is pushed downwards. The faulting occurred because the Cocos Plate was pushing and sliding beneath the North American Plate, primarily along the coasts of Michoacán and Guerrero states in Mexico.

The shockwaves of the earthquake hit the mouth of the Balsas River on the coast at 7:17 am, and they reached Mexico City, which is about 350 kilometers (220 miles) away, two minutes later at 7:19 am. The earthquake on September 19 was a

complex event with two epicenters, and the second movement happened 26 seconds after the first. Due to multiple ruptures in the fault, the event lasted a long time. The shaking lasted for more than five minutes in some places along the coast, and parts of Mexico City shook for about three minutes, with an average shaking time of 3 to 4 minutes. It is estimated that the movement along the fault was about three meters (9.8 feet).

The energy released during the main event was equivalent to the explosion of approximately 1,114 nuclear weapons. The earthquake was felt over an area of 825,000 square kilometers, reaching as far as Los Angeles and Houston in the United States. Although the fault was located just off the Pacific coast of Mexico, the effect on the sea was relatively small. The earthquake generated several tsunamis, but they were small, ranging from one to three meters in height.

The greatest damage caused by the earthquake was related to human loss. The earthquake mainly affected buildings due to resonance in the lakebed sediments and the long duration of the shaking. The most damaged buildings were those with between 6 and 15 floors. An interesting feature was that many buildings saw their upper floors collapse, leaving the lower floors relatively intact. In other cases, the ground floors of buildings were designed as parking areas, open lobbies, or large commercial spaces. These "soft" floors were particularly flexible and tended to collapse after prolonged shaking. Some types of foundations, especially those involving piles driven into clay and held in place by friction, proved to be weak. For example, a nine-story building toppled over because its piles were completely pulled out of the ground.

At the time of the earthquake, Mexico City had one of the strictest building codes, based on experiences from earthquakes in 1957 and 1979. However, these codes were not designed to handle the level of seismic activity experienced in 1985. This

disaster highlighted the need for continuous improvement and adaptation of building standards to ensure better safety and resilience in future earthquakes.

Bibliography:

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- The Editors of Encyclopaedia Britannica. (2024, 14 agosto). Mexico City earthquake of 1985 | History, Facts, & Response. Encyclopedia Britannica. https://www.britannica.com/event/Mexico-City-earthquake-of-1985

6. An earthquake was recorded in three different stations. Station A is located at coordinates (0 Km, 0 Km), station B is located 150.56 Km north of station A, while station C is located 95.50 Km west of station A. Assume that the velocity of the S-wave is 3,000 m/s and that the velocity of the P-wave is 5,196 m/s. After analyzing the acceleration time series, the time difference between the arrival of the first P and S waves in stations A, B, and C is 6.12s, 18.38s, and 9.19s, respectively. Find the coordinates of the epicenter and provide a sketch (Assume the depth of the focus equals 0 Km).

Station A (0,0)

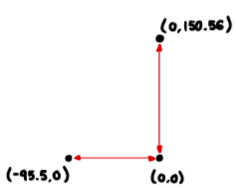
Station B (0, 150.56)

Station C (-95.50, 0)

Velocity S-wave 3000 m/s

Velocity P-wave 5.196 m/s

Depth of the focus equals 0 Km



$t_A = 6.12\,s$

$t_B = 18.38\,s$

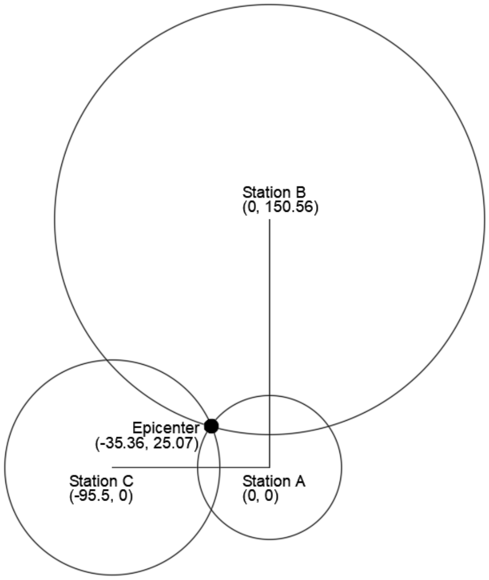
$t_C = 9.19\,s$

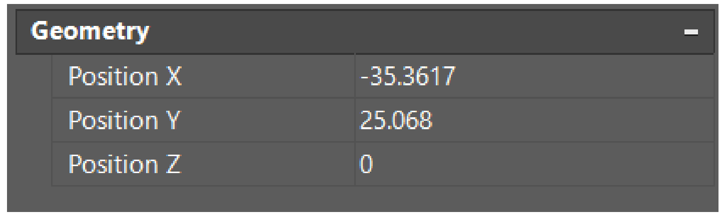
$\Delta t = \frac{r}{V_s} - \frac{r}{V_p} \rightarrow$

t_A	t_B	t_C
$6.12\,s = \frac{r}{3000} - \frac{r}{5196}$	$18.38\,s = \frac{r}{3000} - \frac{r}{5196}$	$9.19\,s = \frac{r}{3000} - \frac{r}{5196}$
$r = 43{,}441.9672$ m	$r = 130{,}467.868$ m	$r = 65{,}233.934$ m
$r = 43.442$ Km	$r = 130.468$ Km	$r = 65.234$ Km

Epicenter

$x = -35.3617$ Km
$y = 25.068$ Km
$z \approx 0$ Km





7. Estimate the vertical distance between the surface and the deepest part of the rupture of an earthquake with Mw=7.37, that ruptured a total length of 128 Km along the surface. The shear modulus of the crust is 3x10^{10} N/m2, the dip angle is 29°, the average displacement was 11.20m (you can assume that the whole block moved this distance) and the rake angle is 34°.

$M_w = 7.37$

Total length = 128 Km ≈ 128,000 m

Modulus of the crust (μ) = 3×10^{10} N/m²

dip χ = 29°

average displacement = 11.20 m

rake χ = 34°

Estimate the vertical distance between the surface and the deepest part of the rupture of an earthquake

$M0 = \mu A \bar{u}$

$M0 = (3 \times 10^{10}\ N/m^2)(128{,}000\ m)\, B\ (11.20\ m)$

$M0 = 4.3008 \times 10^{16}\ B\ N/m$

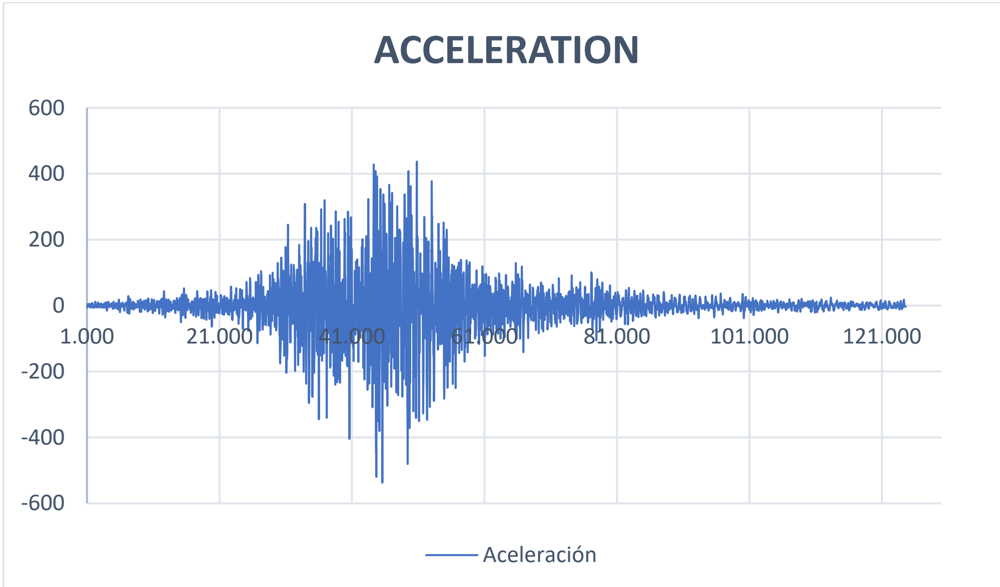
$M_w = \frac{2}{3} \log_{10} M0 - 6.03$ ← Sustituimos valores y despejamos para la variable

$7.37 = \frac{2}{3} \log_{10} (4.3008 \times 10^{16}\ B) - 6.03$

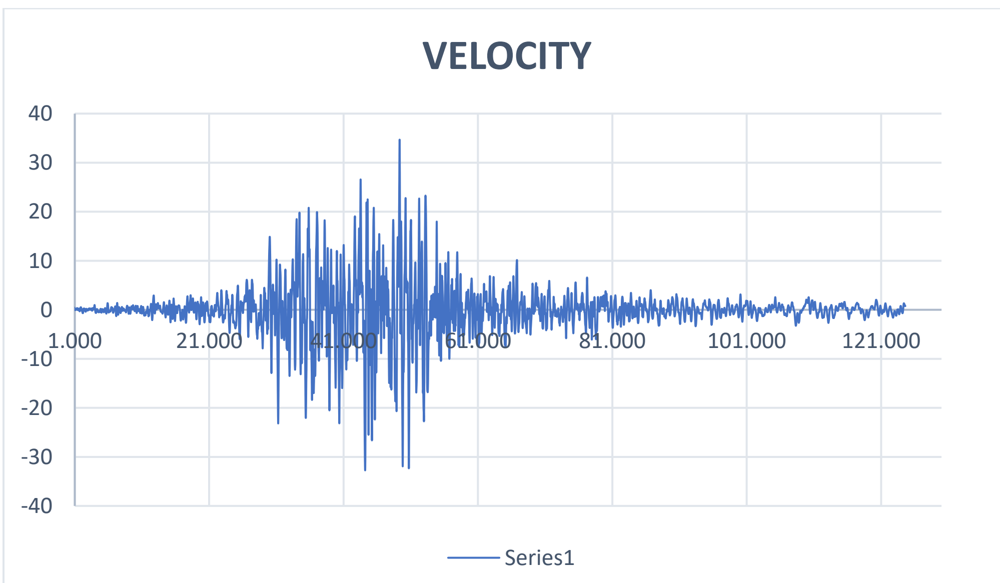
$13.4 = \frac{2}{3} \log_{10} (4.3008 \times 10^{16})\, B$

$B = 2{,}927.189\ m$

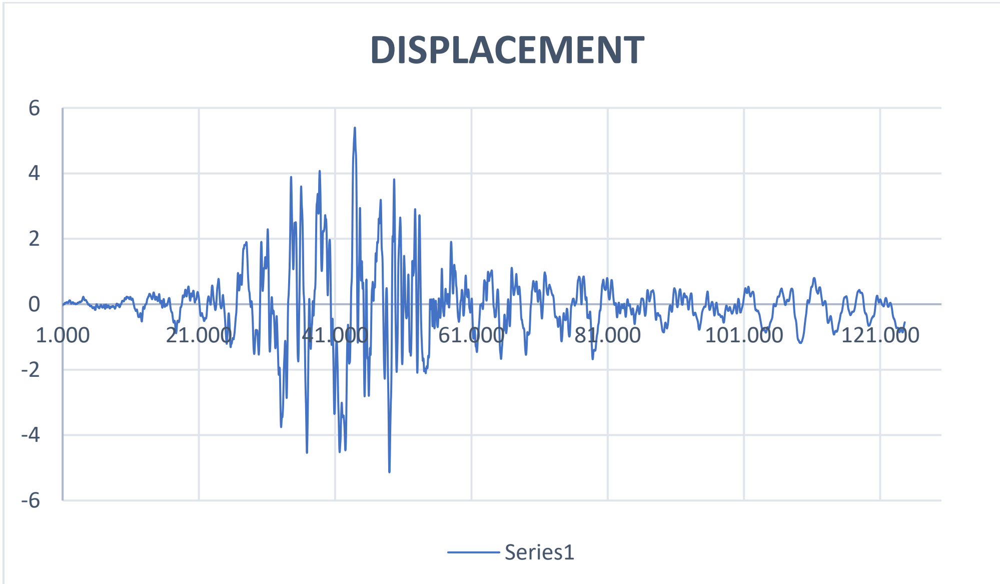
8. You are given the earthquake acceleration time series of the 2010 Llolleo earthquake with units of g. The discretization of the recording is Δt = 0.005s (first row of the vector in the file). Describe how to compute and plot the acceleration, velocity, and displacement time series. Indicate in those plots the peak ground acceleration, peak ground velocity, and peak ground displacement.



Max = **436.92759**
Min = **-537.59781**
Peak ground acceleration **537.59781** **cm/s2**



Max = **34.6997144**
Min = **-32.740395**
Peak ground velocity **34.6997144** **cm/s**



Max = **5.40007733**

Min = **-5.138655**

Peak ground displacement **5.40007733 cm**